

PATENT APPLICATION

SS-734-06

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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To the Commissioner of Patents and Trademarks,

Your petitioners, Hiroshi MATSUSHITA, a citizen of Japan
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10 94115; and, Paul W. MCBURNEY, a citizen of the United States
and a resident of San Francisco, California, whose post office
address is 571 Second Avenue, San Francisco, CA 94118, pray
that letters patent may be granted to them for a

15 COMPUTING NETWORK PATH DELAYS SO ACCURATE ABSOLUTE
TIME CAN BE FORWARDED FROM A SERVER TO A CLIENT

as set forth in the following specification.

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COMPUTING NETWORK PATH DELAYS SO ACCURATE ABSOLUTE
TIME CAN BE FORWARDED FROM A SERVER TO A CLIENT

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1. Field of the Invention

10 The present invention relates to using a network server that knows accurate, absolute time to communicate that to a network client, and more particularly to methods and systems for estimating the network path delays between the server and client so the time information can be appropriately corrected.

2. Description of the Prior Art

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Global positioning system (GPS) receivers use signals received from several earth-orbiting satellites to determine navigational data such as position and velocity. A navigation receiver that has just been turned on does not yet know how much its crystal oscillator is in error, nor does it know accurate time. Both these are needed to find and lock on to the satellite transmissions. During initialization, a navigation satellite receiver will search through both the time and frequency spectrums to find available satellites. But a blind search can take a very long time. So a navigation satellite receiver can be assisted in its initialization by another one that does know accurate time.

25 A problem arises in communicating accurate, absolute time over a network. There is no guarantee that any particular data packet sent out on the Internet will actually be delivered at its destination. Best efforts are used. Such data packets will also follow different connections through the network and experience a highly variable set of delays. So it is uncertain how long any one data packet will be

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delayed. If a server on a network knows accurate time and transmits it, the uncertain arrival time of the data packets will degrade the worth of the time information.

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SUMMARY OF THE INVENTION

10 It is therefore an object of the present invention to provide an Internet based service that can provide correct time information to a client.

It is another object of the present invention to provide a method and system for improving the time needed for initialization of network client navigation devices.

15 It is a further object of the present invention to provide a satellite-navigation system that is inexpensive.

Briefly, a navigation-satellite receiver support data network embodiment of the present invention comprises a server connected to the Internet to provide initialization
20 information to clients for faster cold starts. The server includes a GPS receiver that provides for tracking of a constellation of navigation satellites. When a client is started cold, time and frequency are initially unknown to it. Test messages are sent back and forth over the Internet and a
25 path delay time is computed from the average of the quickest transit times. This yields the offset time between the server's time system and the client's time system. The server sends current time information to the client, and the computed path delay is added. The client can then compute correct time
30 from the server and path delay information, and thereby select much sooner which satellites are correct to search. An advantage of the present invention is that a system and method are provided that substantially improve the time-to-first-fix of client navigation receivers.

Another advantage of the present invention is that a system and method are provided that lead to reduced equipment and usage costs.

These and other objects and advantages of the present invention will no doubt become obvious to those of ordinary skill in the art after having read the following detailed description of the preferred embodiments which are illustrated in the various drawing figures.

IN THE DRAWINGS

Fig. 1 is a functional block diagram of a network system embodiment of the present invention wherein a server is assisting a client with time information communicated over the Internet;

Fig. 2 is a schematic diagram of the relationships between time-of-launch, time-of-flight, and time-of-receipt of data packets communicated over the Internet as in the network system in Fig. 1; and

Fig. 3 is a scattergram of test results that were obtained when trial messages were sent between a server and a client and back again.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Fig. 1 illustrates a network system 100, in an embodiment of the present invention, that includes a server system (system-1) 102, a client system (system-2) 104, and an intervening computer network 106 such as the Internet. The server system 102 includes a navigation satellite receiver

that has locked onto and is tracking a constellation of navigation satellites 108, 110, and 112. Some of these may also be visible to the client system 104. Another constellation of navigation satellites, including 114 and 116 is visible to client system 104. The client system 104 includes its own navigation satellite receiver, but such may not have yet locked onto and be tracking its constellation of navigation satellites 112, 114, and 116.

The server system 102 is intended to be always on and tracking its constellation of navigation satellites 108, 110, and 112. It is then able to discern accurate, absolute system time and may also provide current ephemeris, troposphere, ionosphere, and other information to other, not-yet-initialized navigation satellite receivers. Such information all needs to be determined during initialization, and spoon feeding any of it from another source will dramatically improve time-to-first-fix.

Fig. 1 illustrates an Internet infrastructure that is able to spoon-feed, or aid, any number of client systems online. Such information can be provided as a service, on a per-use charge or as a subscription.

Critical to embodiments of the invention is the providing of accurate, absolute system time information by the server system 102 to the client system 104 over the Internet 106. Also critical is the ascertaining of the path delay encountered by data packets traversing the Internet 106 between the server system 102 to the client system 104. The path delay estimate may be added into the time information sent by the server system 102, e.g., so it arrives at client system 104 at the time stated in the payload. Or, the payload of the data packet may have the correct time when it was launched and the client system 104 adds in the estimated path delay to arrive at correct time after its travel and delivery.

The advantages of the present invention are realized when the client system 104 is just being turned on and needs to have frequency information on its own local oscillator and the correct, absolute system time. Until these quantities are known, the client system will have to engage in a trial-and-error search. For example, postulating a variety of possible times and frequencies.

Fig. 2 represents an infrastructure-aiding system 200 in which a system-1 is a server and a system-2 is a client. Fig. 2 illustrates the problem caused by the indeterminate delays experienced by data packets traversing the Internet. At a time T_1 , a time data packet 202 is launched at system-2. The time-of-flight is latency L_1 . The time of launch is determined at system-2 by working back from its receipt of data packet 202 at time T_2 , e.g., $T_2 - L_1 = T_1 - \text{offset}$. And, $T_2 = T_1 + L_1 - \text{offset}$. At system-1, the time of receipt at system-2 is $T_1 + L_1$. A turn-around process 204 launched an answering data packet 206 at time T_3 , e.g., $T_3 = T_4 - L_2 - \text{offset}$. The latency L_2 is the time-of-flight. The answering data packet 206 arrives at system-1 at T_4 . System-2 puts this at $T_3 + L_2 = T_4 - \text{offset}$. A simultaneous equation can therefore find the "offset" variable.

Experiments were conducted in a real network to determine actual values for $T_1 - T_2$ and $T_4 - T_3$. The test messages were observed to have been delayed by various amounts.

Fig. 3 represents the results of a series of tests. The fastest times for $T_4 - T_3$ and $T_1 - T_2$ tended to bunch up against two limit lines with a gap in between. Such gap was on the order of fifteen milliseconds. The estimated offset was then taken as the centerline of the gap. The calculation of the offset is not the average of all $T_4 - T_3$ and $T_1 - T_2$. Instead, only the maximum values of $T_1 - T_2$ and the minimum values of $T_4 - T_3$ are used. It follows that $\text{MAX}(T_1 - T_2) < \text{offset} < \text{MIN}(T_4 - T_3)$. Reducing this to a formula for offset,

$$offset = \frac{T1 - T2 + \left(\frac{L1}{L2}\right)(T4 - T3)}{1 + \left(\frac{L1}{L2}\right)}$$

Therefore a method embodiment of the present invention
5 sends a series of test messages from the server to the client
and back. The values for the maximum values of T1-T2 and the
minimum values of T4-T3 are averaged to find the offset value.
Correct, absolute time at the server plus the offset time,
yields the correct absolute time at the client. Such time is
10 used by the client to initialize itself for quicker tracking
and lock onto the satellites in its constellation.

Although the present invention has been described in
terms of the presently preferred embodiments, it is to be
understood that the disclosure is not to be interpreted as
15 limiting. Various alterations and modifications will no doubt
become apparent to those skilled in the art after having read
the above disclosure. Accordingly, it is intended that the
appended claims be interpreted as covering all alterations and
modifications as fall within the "true" spirit and scope of
20 the invention.

What is claimed is: